Teaching Professionalism, Design, & Communications to Engineering Freshmen

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Abstract

A new course was developed to introduce biological systems engineering and agricultural engineering freshmen to professional ethics, engineering design, and technical communication. Using guided design and the "Seven Habits" as a base, the new course integrated these foundational topics using group and individual assignments. Presentations from practicing engineers reinforced these topics and provided the students with a look at several career opportunities in agricultural and biological engineering. The integration of these topics was effective, although the students considered the workload to be heavy for a two credit (semester) course.

Introduction

The design process is well established as a central part of engineering education, due not only to its obvious importance, but to stringent Accreditation Board for Engineering and Technology (ABET) requirements in this area. Industry continually calls for improved teaching of engineering design[1,2,3]. Professionalism (or ethics) and communications as part of engineering education have also received a strong emphasis from industry and others[3,4,5,6]. Again, ABET has contributed specific requirements, while many in industry[3,4] have strongly encouraged academia to emphasize these skills.

Often, however, significant teaching of design is saved for the end of the curriculum in the capstone design course. Professionalism has typically received even worse treatment, being completely ignored until either the capstone design course or a senior seminar course. On the other hand, some communications skills are usually included early in the curriculum by way of required freshman composition courses. But, technical writing skills are also frequently neglected until late in the curriculum. Instruction in technical writing may well be limited to a single course in business or technical writing taught by the same people who teach freshman composition.

In the Department of Agricultural Engineering at the University of Idaho, we feel that the emphasis on these three areas of engineering education is legitimate. However, we believe that students will be better served in these areas when they are introduced to the topics early so they can build on a solid foundation of design, professionalism and communications throughout their curriculum. We also feel it is important for the students to get to know each other, to work together, and learn about the biological and agricultural engineering professional opportunities. As a result, in 1993 we developed an introductory freshman course with a strong emphasis on problem solving for design, professionalism, communications, and teamwork.

Foundations for the Freshman Course

Design for Freshmen

Dr. Charles Wales and his coworkers at the Center for Guided Design at West Virginia University have developed material, including a textbook[7], for teaching design methods to freshman engineering students. They have titled their decision making strategy the "guided design" process[8]. It provides an accurate model for the students to use in bringing the appropriate facts and thinking to bear on complex open-ended problems, as well as clear guidelines to help students solve single answer problems. Their research showed significant improvement in both retention rate and final GPA of engineering students who were taught guided design as freshman as compared to those who were not[9]. Other research indicated that student classroom performance (on tests) was significantly improved by the use of guided design[10].

Guided design is based on a hierarchical model of thinking skills in which the five thinking operations, shown in Figure 1, are ultimately used by effective problem solvers (i.e., engineers!) to arrive at a good solution. This hierarchical model of the thinking process of good problem solvers was based on many years of observation by researchers at the Center for Guided Design and elsewhere. There are two major thrusts in applying the guided design concept to engineering education. First, for solving open-ended problems, the five thinking operations are essentially the model that students can use for problem solving. The second thrust is applying these thinking operations to single answer problems.

Other Thinking Skills		Thinking Operations
Internal & external communication Creative and critical thinking Analysis, synthesis, & evaluation	serve →	1. Define the situation 2. State the goal 3. Generate ideas 4. Prepare the plan 5. Take action & evaluate

Figure 1. The five thinking operations and other thinking skills that serve them.

For single answer problems, the *situation is defined* and the *goal* given in the problem statement. There is no need to *generate ideas* to solve such problems because using equations is usually the only option available in the classroom. Since *taking action* only requires running a few numbers through the calculator, the whole issue is just *preparing the plan*, i.e., determining the needed equations and how to use them.

Preparing a GENI plan is the guided design method for logically working through any number of equations to arrive at the single answer solution. This acronym is for Goal-Equation-Need-Information, a logical method to use equations and other information to solve single answer problems. Figure 2 illustrates the use of GENI (examples are in the literature[7,8]).

Professionalism for Freshmen

There are a world of ideas about professionalism and ethics that one might try to teach engineering students. We chose to use the Seven Habits espoused by Stephen Covey in his best-selling book, *The Seven Habits of Highly Effective People*[11]. This book has proven itself to be an effective guide for living with fairness, integrity, honesty, and human dignity in today's world. It has received widespread use in businesses in the United States as a guide for ethical practice in business.

	Goal	Equation	Need	Information
1	First goal is the goal from problem statement.	Write equation that can be solved for the goal.	List quantities needed to calculate goal from equation.	List known information (all other needs become new goals).
2	Next goal is a need that was not in the known information.	Write down new equation that can be solved for the new goal.	List quantities needed to calculate new goal from new equation.	List known information (all other needs become new goals).
3	Repeat with new goals until all needs are known information.			

Figure 2. GENI method for preparing a plan with single answer problems.

The basic premise of the book is that there are timeless principles that govern human effectiveness. Covey explains that these principles are self-evident and we can probably all find them within ourselves if we look. These include self-evident principles such as human dignity that was so nobly espoused in the United States Declaration of Independence. Covey maintains that when these principles are internalized into habits they enable people to deal with situations and other people with appropriate professionalism. The book then proceeds to define and explain how to incorporate these Seven Habits into your life:

1. *Be Proactive:* Principles of Personal Vision,
2. *Begin with the End in Mind:* Principles of Personal Leadership,
3. *Put First Things First:* Principles of Personal Management,
4. *Think Win/Win:* Principles of Interpersonal Leadership,
5. *Seek First to Understand, Then to Be Understood:* Principles of Empathic Communication,
6. *Synergize:* Principles of Creative Cooperation, and
7. *Sharpen the Saw:* Principles of Balanced Self-Renewal.

Communications for Freshmen

Most universities with engineering curricula have strong requirements for freshmen to acquire a reasonable level of proficiency in English composition. The University of Idaho has a typical requirement, two semesters of English composition for all freshmen. Technical writing and oral communication, arguably the most important communications for engineers, usually receive far less attention in engineering curricula. Standard engineering technical oral and written report formats were used in this course. They were slightly modified versions of the same format used in upper division biological systems and agricultural engineering laboratory courses.

The Freshman Engineering Course

The Department of Agricultural Engineering at the University of Idaho offers two engineering degrees for undergraduates. The degree in Agricultural Engineering is a fairly traditional broad program with a typical engineering core curriculum and upper division courses in soil and water, power and machinery, agricultural structures, and agricultural processing. The second degree, Biological Systems Engineering, has a much greater emphasis on chemistry and biology in both the lower and upper divisions and more flexibility with upper division courses for the student to acquire depth in selected areas of biological systems engineering.

The freshman engineering course, "Engineering for Living Systems," was developed to integrate design, professionalism, and technical communications and provide a foundation in these topics on which the students can build during their academic and professional careers. The course was two semester credits with one hour of lecture and three hours of laboratory each week. The basic course structure is shown in Figure 3. Material on single answer problem solving, the GENI method, in Text 1[7] was covered during the weekly lectures. The laboratory sessions usually alternated between group projects solving an open ended problem using guided design and covering one of the seven habits in Text 2[11].

week	Lecture (1 hr)	Laboratory (3 hr)
1	Ch. 1, *GENI*	Proj. 1: *The Puzzle,* MBTI
2	Ch. 2: *Thinking* HW due (Ch. 1)	Hab. 1: Be Proactive, MBTI (No reports)
3	Ch. 3: *The 1st Law* HW due (Ch. 2)	Proj. 2: *Survival school* Paper due (Hab. 1)
4	Visit Library HW due (Ch. 3)	Hab. 2: *Begin w/ end . . .* Oral, writ. reports (Proj. 2)
5	Ch. 4: *Measurements*	Guest Lecturer Paper due (Hab. 2)
6	Ch. 5: *Problems* HW due (Ch. 4)	Proj. 3: *The "Thing"*
⋮	⋮	⋮

*Chapter in Text 1, Thinking with Equations.
Proj. = Open-ended guided design project.
Hab. = Discussion of Habit in Text 2, *The Seven Habits of Highly Effective People.*

Figure 3. Partial syllabus showing basic course structure.

There were five major laboratory projects in which students in groups were given open-ended problems. The five open-ended problems were central to understanding the guided design process. These five projects are listed on Figure 4 with a brief explanation of the objectives of each project for helping the students learn how to think through open-ended problems guided by the five thinking operations. A conclusion that we stressed from the Seven Habits is that you have to be trusted to be part of a design team. You have to be honest with yourself and voice your thoughts to be a significant part of the group. Oral presentations were also required of the students for presenting results of the group projects. Oral reports were evaluated by other students. All reports (oral and written) received one-half of the grade for presentation and one-half for technical content.

Communication within the student groups was also emphasized. At the first laboratory session, all students took the Meyers-Briggs type indicator test. A psychologist discussed the results with the students at the second session. She explained in detail the significance of the characteristics of the personality types, with emphasis on effective teamwork; how to interact with different types so that people's different strengths are used to benefit the group. We emphasized that to completely communicate a person must: 1)listen, 2)talk, 3)read, and 4)write.

Project	Major Objectives
1. The Puzzle	See importance of a team plan. Recognize the 5 thinking operations.
2. Survival School	Importance of group working together. Need for appropriate knowledge. Importance of using each thinking operation correctly. Thoroughly ***define the situation***.
3. Elk-Car Accidents	Working outline of entire process. Understand the "Practitioner." Properly ***state the goal*** (distinguish from solution areas).
4. The "Thing"	Understand scientific method used by the "Researcher" to ***Generate ideas.*** Researcher and Practitioner use same 5 operations. Take action and evaluate results.
5. Icy Bridge	Apply a technical solution to a problem. Organize by topic to generate ideas. Thoroughly ***prepare the plan*** with technical information.

Figure 4. Progression of material in the open-ended design projects.

As can be seen in Figure 3, there were also guest lecturers who spoke during the laboratory sessions. Figure 5 shows all of the topics included in the guest lectures. The practicing biological and agricultural engineers spoke to the class about professionalism and the practice of engineering. These guest lectures reinforced the importance and conduct of professionalism and communications in engineering. There were additional sessions on using personal computers— primarily on using spreadsheets for engineering calculations and presentations.

Experiences and Student Feedback

The course has been taught twice, in the fall of 1993 and in the fall of 1994, with 14 and 12 students, respectively. The students have been 23% Biological Systems Engineering majors and 77% Agricultural Engineering majors; 12% female and 88% male. These were the first two semesters that the Biological Systems Engineering program was available. Greater numbers of Biological Systems Engineering majors are expected as the program becomes better known in Idaho.

Engineering Guest Lectures	
Consulting Engineering	emphasizing importance of good oral and written communications and professional ethics.
Environmental Engineering	demonstrating how biology, chemistry, and biological systems are used in engineering practice.
Industrial Engineering	showing how large scale and industrial projects are managed (including tour).
Res. & Devel. Engineering	demonstrating the importance of the scientific basis of engineering practice.
International Engineering	emphasizing the social and cultural implications of engineering practice.
Other Guest Lectures	
Personality Types	a psychologist's look at the impact of personality types on teamwork.
The Library	how to find what you need without wasting time and effort in the library.
Cooperative Education	how to enhance your academic experience and increase career opportunities.

Figure 5. Guest lectures that brought the real world to the freshman course.

The performance and application of material for most students was good. However, student feedback has been mixed for several aspects of the course. In regard to the use of the GENI method and guided design for solving single answer problems, many students understood and used the method well. Some of their comments were: the most valuable aspects of this course were "learning GENI and the thinking process they [the instructors] taught to solve problems" and "The material covered was very helpful, mainly the GENI method." Unfortunately, a significant minority of students in 1994 simply missed the point even after a full semester. Many of this group were simply not serious about doing the homework.

However, a few students attempted the homework and still did not grasp the basic methodology in GENI. One problem in these cases is that some view this as just another technique to memorize for this course[8] (only); but, in fact, due to this outlook they neither memorized nor understood it very well. However, this points out the need to be extremely careful with the first few lectures on GENI to be sure everyone gets on board. In 1993 nearly everyone did get on board and there was good understanding of the method by mid-semester. In 1994, when we discovered at mid-semester that some students did not really understand, it was too late. Teaching efforts after that time did not significantly help most of those students. Thus, it is very important to get everyone started well with GENI in the beginning.

The second aspect of guided design is solving open-ended problems. The groups were guided through the design process outlined in Figure 1 in the five laboratory projects shown in Figure 4. These were well proven projects developed at the Center for Guided Design with only minor modifications. The majority of students learned well in these laboratory sessions and understood the basic use of the five thinking operations by the end of the course. But few students in 1994 showed serious enthusiasm for the projects or for the use of the five thinking operations. There are probably two main reasons for this lack of enthusiasm.

First, the Agricultural Engineering majors (88% of the class) generally felt the topics were not useful to them and apparently failed to grasp the fact that methods, not topics, were being taught. We will start earlier and try harder to convince future students of the importance of the methods regardless of the topics. Other projects might be developed on agricultural topics, but that may require more time than is practical. The second reason for lack of student enthusiasm is the promotion of the projects by the instructor. Showmanship and cheer leading would go a long way in creating student enthusiasm in 1.5 to 2.5 hour projects. The instructor will try.

There has been an equal positive response from the students about professionalism and ethics issues covered in the seven habits as with the guided design issues. However, there has been very little negative response about the habits. This may be because there were few difficult or long assignments with the habits, so that no one was inspired to complain. It was also clearer to all students that these issues were important to biological and agricultural engineers. The practicing engineers strongly reinforced the importance of professionalism which helped many students truly comprehend this issue.

There has been little direct feedback from the students on the communications aspects of the course. Students seemed to find the oral presentation sessions (from each project) to be the most enjoyable thing about the guided design part of the course. Most students did well with the oral reports and showed improvements during the course. There were complaints that too many reports were required during the course, but this was probably just a reflection of the strong consensus that there was too much work in this course, in general. Four technical reports were required of the students during the course. Three reports were group projects and one other report was required individually of all students. The reinforcement from the guest lecturers was instrumental in encouraging the students about communications.

Many of the students were uncomfortable with the rigorous format expected of them for technical reports. They did make progress during the semester, but will need further work in later courses before they are fully prepared for writing engineering reports. More emphasis may need to be placed on helping the students be comfortable with technical writing in this course also.

Conclusions

We formulated the following conclusions based on the analysis of student performance and response after teaching this freshman course twice:

1. Design, professionalism, and communications can be effectively combined for freshmen engineers.
2. Care is required to avoid too much material and too much work from including all desirable issues in this introductory course.
3. Guided design must be well presented and promoted in a freshman course to be well received by all students.
4. It is important to have practicing engineers visit with the class about the engineering profession, communication, and opportunities

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